FORM PTO-1390 (Modified) (REV 11-2000) U S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE ATTORNEY'S DOCKET NUMBER JC10 Rec'd PCT/PTO 05 NOV 2001

# TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

112740-326

U.S APPLICATION NO. (IF KNOWN, SEE 37 CFR
09/979540

| INTERNATIONAL APPLICATION NO | INTERNATIONAL FILING DATE | PRIORITY DATE CLAIMED |
|---|---|---|
| **PCT/EP00/03625** | **20 April 2000** | **05 May 1999** |

TITLE OF INVENTION
**METHOD FOR ASSESSING ROUTES IN A COMMUNICATIONS NETWORK**

APPLICANT(S) FOR DO/EO/US
**Luigi Bella et al.**

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

**Items 13 to 20 below concern document(s) or information included:**

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☒ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U S C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

| U.S. APPLICATION NO (IF KNOWN, SEE 37 CFR | INTERNATIONAL APPLICATION NO | ATTORNEY'S DOCKET NUMBER |
|---|---|---|
| 09/979540 | PCT/EP00/03625 | 112740-326 |

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24. The following fees are submitted:.

**BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5)) :**

| | | | CALCULATIONS | PTO USE ONLY |
|---|---|---|---|---|
| ☐ | Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO . . . . . . . . . . . . | **$1040.00** | | |
| ☒ | International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO . . . . . . . . | **$890.00** | | |
| ☐ | International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO . . . . . . . . . . . . | **$740.00** | | |
| ☐ | International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) . . . . . . . . . . . . | **$710.00** | | |
| ☐ | International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) . . . . . . . . . . | **$100.00** | | |
| | **ENTER APPROPRIATE BASIC FEE AMOUNT =** | | **$890.00** | |
| | Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)). | | **$0.00** | |

| CLAIMS | NUMBER FILED | NUMBER EXTRA | RATE | | |
|---|---|---|---|---|---|
| Total claims | 9 - 20 = | 0 | x $18.00 | **$0.00** | |
| Independent claims | 1 - 3 = | 0 | x $84.00 | **$0.00** | |
| Multiple Dependent Claims **(check if applicable).** | | | ☐ | **$0.00** | |
| **TOTAL OF ABOVE CALCULATIONS =** | | | | **$890.00** | |
| ☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2. | | | | **$0.00** | |
| **SUBTOTAL =** | | | | **$890.00** | |
| Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). + | | | | **$0.00** | |
| **TOTAL NATIONAL FEE =** | | | | **$890.00** | |
| Fee for recording the enclosed assignment (37 CFR 1 21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐ | | | | **$0.00** | |
| **TOTAL FEES ENCLOSED =** | | | | **$890.00** | |
| | | | | **Amount to be: refunded** | $ |
| | | | | **charged** | $ |

a. ☒ A check in the amount of **$890.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **02-1818** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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SIGNATURE

**William E. Vaughan**
NAME

**39,056**
REGISTRATION NUMBER

**November 5, 2001**
DATE

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| **CERTIFICATE OF MAILING BY "EXPRESS MAIL" (37 CFR 1.10)**<br>Applicant(s): **Luigi Bella et al.** | | | Docket No.<br>**112740-326** |
|---|---|---|---|
| Serial No. | Filing Date | Examiner | Group Art Unit |
| | | | |

Invention: **METHOD FOR ASSESSING ROUTES IN A COMMUNICATIONS NETWORK**

I hereby certify that the following correspondence:

**Transmittal letter to the United States Designated/Elected office in duplicate, International application as originally filed, English translation, Preliminary Amendment, IDS, PTO 1449, references, search report, Prel. Examination Report, filing fee $890.00, postcard**

*(Identify type of correspondence)*

is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 in an envelope addressed to: The Assistant Commissioner for Patents, Washington, D.C. 20231 on

**November 5, 2001**
*(Date)*

**Robert Bucchieri**
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IN THE UNITED STATES ELECTED/DESIGNATED OFFICE
OF THE UNITED STATES PATENT AND TRADEMARK OFFICE
UNDER THE PATENT COOPERATION TREATY-CHAPTER II

**PRELIMINARY AMENDMENT**

| | | | |
|---|---|---|---|
| APPLICANTS: | Luigi Bella et al. | DOCKET NO.: | 112740-326 |
| SERIAL NO: | | GROUP ART UNIT: | |
| FILED: | | EXAMINER: | |
| INTERNATIONAL APPLICATION NO:: | | PCT/EP00/03625 | |
| INTERNATIONAL FILING DATE | | 20 April 2000 | |
| INVENTION: | METHOD FOR ASSESSING ROUTES IN A COMMUNICATIONS NETWORK | | |

Assistant Commissioner for Patents,
Washington, D.C. 20231

Sir:

Please amend the above-identified International Application before entry into the National stage before the U.S. Patent and Trademark Office under 35 U.S.C. §371 as follows:

**In the Specification:**

Please replace the Specification of the present application, including the Abstract, with the following Substitute Specification:

SPECIFICATION

TITLE OF INVENTION

METHOD FOR ASSESSING OF ROUTES IN A COMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

Communications networks are normally either in the form of packet-oriented networks or line-oriented networks. In this case, packet-oriented networks are more suitable for transmitting information without any real-time nature, such as data, e-mails or files, while line-oriented networks are highly suitable for

transmitting information with a real-time nature, such as voice or moving images. However, as line-oriented and packet-oriented networks converge, voice and moving-image information is also increasingly being transmitted in packet-oriented networks. Examples of packet-oriented networks are the Internet or ATM (= Asynchronous Transfer Mode) with the expression ATM also occasionally being used as a synonym for B-ISDN (= Broadband Integrated Services Digital Network). The packet-oriented network technology will be explained in more detail in the following text using the example of ATM.

A characteristic feature of packet-oriented networks is the packet-oriented transmission of information. In ATM networks, the information is, for example, split into packets of equal length - also referred to as "ATM cells" - which have a cell-header including 5 bytes, and an information section (payload) including 48 bytes. In this case, the individual cells are allocated by the cell headers to specific information streams - also referred to as "virtual connections". In contrast to, for example, a line-oriented TDMA method, in which timeslots are allocated from the start to different types of data traffic, the information streams that arrive at an ATM interface are segmented into the said 53-byte cells, and these cells are then sent onward sequentially in the sequence in which they were produced. The multiplexing method used for TDMA is also referred to as "static multiplexing", while that used for ATM is referred to as "statistical multiplexing". Owing to the flexibility of statistical multiplexing, the information streams in the case of ATM may have any desired data rates, while the data rate for the individual information streams - also referred to as "connections" - when using static multiplexing is fixed, for example, at 64 kbps in the case of ISDN, owing to the fixed association between the timeslots and the information streams.

As a consequence of this difference, the routing of a requested connection in packet-oriented networks is dependent on the available capacity remaining on a route while, in line-oriented networks, it is in principle independent of the load level of the individual transmission paths. For example, on a route in a line-oriented network along which, for example, 30 connections can be carried, using a TDM method, in fixed allocated timeslots each having a capacity of 64 kbps, a further connection also can be set up when 29 connections already have been set up, since the further connection does not require a higher data rate than the

remaining capacity of 64 kbps that is still available, since its data rate is constant. However, only connections for which a data rate of less than 30 Mbps has been requested can be set up along a route in a packet-oriented network with an assumed remaining capacity of 30 Mbps. Connections with a higher data rate are, however, rejected. If any alternative routes exist, they can be set up by way of a substitute along an alternative route with sufficient remaining capacity. However, renewed routing is required in order to determine an alternative route.

Various routing methods are known by which it is possible to determine routes in networks. One option is referred to as "source routing", in which the complete route to a destination switching node is determined, starting from an initial switching node. For ATM networks, for example, the ATM forum has demanded source routing for the purposes of the PNNI (= Private Network-Network Interface) Specification. In this case, the route is determined by the initial switching node and then, when setting up the connection, the calculated route is transmitted to the switching nodes along the route by signaling. A further option is referred to as "Hop-by-Hop routing" in which each switching node along a route recalculates the rest of the route, or the next section of the route. This method is used, for example, in the Internet or in ATM networks without source routing.

What are referred to as flooding methods have been proposed in order to exclude from the routing process those routes which use overloaded or interrupted transmission paths. In this case, all the switching nodes measure the traffic levels of the transmission paths connected to them at defined times, and pass this information on to all the other switching nodes within a group. This passing on of information is referred to as "flooding". Flooding also can be carried out when the traffic levels on the transmission paths change significantly; for example, when the actual load level on a transmission path with a total capacity of 150 Mbps differs by more than 10 Mbps from the last load level passed on. For example, the PNNI Specification proposes that methods be used in ATM networks which provide a routing algorithm with the respective traffic levels measured most recently in the switching nodes in the ATM network for those transmission paths which are directly connected to them. In the context of PNNI, reference also should be made to U. Gremmelmaier, J. Püschner, M. Winter and P. Jocher, "Performance

Evaluation of the PNNI Routing Protocol using an Emulation Tool", ISS 97 XVI World Telecom Congress Proceedings, pp 401 - 408.

Routing in line-oriented, public telephone networks is known. In this case, the routing process is normally carried out in a number of steps, since these networks are normally hierarchically constructed since there are generally a large number of switching nodes. In a first step, connections in these networks are routed from an initial switching node on a lower hierarchical level to a switching node on the uppermost hierarchical level and then, in a second step, they are routed within the uppermost hierarchy level to a switching node which represents the connection destination before, finally, being routed in a third step to the destination switching node in a lower hierarchy level. In this case, the first and third steps generally make use of fixed selected routes or, for example if these are interrupted, fixed set alternative routes, while the second step frequently requires only a selection of the transmission path between the two affected switching nodes in the uppermost hierarchy level, since the switching nodes in the uppermost level are virtually completely networked with one another. However, Signaling procedure No. 7, which has been standardized for line-oriented telephone networks, does not support source routing; that is, the initial switching node cannot pass on a route which it calculated. In consequence, the switching nodes along the route do not know the route that already has been traveled over either, so that, when using this routing method, it is possible for loops to occur in the routes in network, for example the Internet, which are not hierarchically structured and/or are only partially networked.

German Patent DE 441356 discloses a dynamic routing method for routing in packet-oriented networks, in which blockages in transmission paths are detected, and the load level on the transmission paths is determined from the frequency of these blockages. The probability of the transmission paths being occupied can be calculated off-line, from destination traffic data, through the use of a routing management processor. The "Forward Looking Routing" algorithm as defined by K.R. Krishnan, T.J. Ott in Forward-Looking Routing, A New State-Dependent Routing Scheme, Teletraffic Science for New Cost-Effective Systems, Networks and Services, ITC-12 (1989) is suitable, for example, for such a calculation. However, this method considers only connections with an identical, constant

bandwidth, such as those which are typical for conventional telephone connections in line-switching networks; that is to say, the bandwidth for one connection is, for example, 64 kbps. For packet-oriented networks such as ATM networks (Asynchronous Transfer Mode), on the other hand, a constant bit rate is an exceptional situation, since connections can be made in accordance with the subscribers' connection requirements with different bandwidths which can vary with time. In addition to the desired bandwidth, for example 1 Mbps, connection requests from subscribers often also contain information relating to the required connection quality.

The present invention, therefore, is directed toward improving the routing for packet-oriented communications networks.

## SUMMARY OF THE INVENTION

A major aspect of the present invention is the assessment of routes in a communications network which includes switching nodes and transmission paths and is, in particular, packet-oriented and possible connection-oriented, and in which link costs which are assigned to the transmission paths are used to form amended link costs, and the routes are assessed as a function of the amended link costs. A major advantage of the present invention is that different assessments of the routes can be obtained by different amendments to the originally assigned link costs. It is thus advantageously possible to control the assessments of the routes by the nature of the amendments to the original link cost; that is, without changing the assessment itself.

According to one embodiment of the method according to the present invention, the amended link costs are intended to be formed by addition of randomly selected real numbers to the link costs, with the absolute magnitude of the real numbers being less than a maximum number, which is selected to be sufficiently small that the link costs are not substantially changed. This advantageously generally results in minimally different route costs for routes which would have identical route costs if the original link costs had not been amended. However, a route with significantly higher route costs than the optimum route costs has an optimum route, even if the original link costs are amended, it has considerably higher route costs than the optimum route costs then determined. Minimal differentiation between the route costs is thus advantageously achieved

only within a group of routes whose route costs with unamended link costs are identical, while the allocation of the routes to such groups of routes with the same route costs, and the sequence of the groups themselves, remain unchanged.

According to one embodiment of the method according to the present invention, an optimum route, which is defined as a function of the amended link costs, is determined via a deterministic routing algorithm. This has the advantage that a deterministic routing algorithm is, in general, less complex than a non-deterministic routing algorithm and thus can be processed more efficiently.

According to another embodiment of the method according to the present invention, the deterministic routing algorithm is in the form of a Dijkstra algorithm. Proven standard software, thus can be used, since the Dijkstra algorithm has actually been known since 1959, and highly efficient and technically proven implementations are available. The optimum route also has minimum route costs.

According to one embodiment of the method according to the present invention, the communications network assesses relevant routes only for one requested connection. This advantageously reduces the number of routes to be assessed and, in consequence, the processing time for assessment of the routes.

According to a further embodiment of the method according to the present invention, the routes are assessed for each request for a connection. The amendment of the link costs, in particular the random selection of the real numbers, advantageously allows for, if there are a number of optimum routes which would have identical minimum route costs if the link costs were not amended, one of these routes to be optionally selected on the requested connection for each connection request, even though a deterministic routing algorithm, that is to say a routing algorithm which determines the same optimum route without amending the link costs in each case, is used to select the route that is optimum for the connection. This considerably reduces the statistically average probability of blocking since the load levels on the transmission paths are more uniform than if the connections were all set up along the same route.

According to one application of the method according to the present invention to a method for setting up a connection in a communications network which includes switching nodes and transmission paths, the connection is set up

along a route which is optimum for this connection. The assessment of the routes is thus advantageously used for the selection of a route. In particular, the randomly controlled amendment of the link costs when there are a number of comparable routes leaves the question open as to which of the routes is optimum for that connection. The connections are not, therefore, automatically set up via the same route, with the load being shared between equivalent routes. This considerably reduces the blocking rates for connections.

According to embodiment of the application of the method according to the present invention, the route which is optimum for the connection is determined by that switching node which processes the request for the connection. This has the advantage that the request can be processed very efficiently, since no messages are required between the node processing request and a further node carrying out the routing.

According to another embodiment of the application of the method according to the present invention, the optimum route for the requested connection is reported to all the switching nodes along the optimum route for the requested connection while the connection is being set up. The present invention can, thus, be used in networks with source routing.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 uses a block diagram to show a communications network with switching nodes and transmission paths.

Figure 2 uses a table to show all the routes which originate from the switching node $K_1$ to the other switching nodes in the communications network illustrated in Figure 1.

Figure 3a uses a table to show the formation, according to the present invention, of amended link costs from link costs assigned to the transmission paths.

Figure 3b uses a table to show the assessment, according to the present invention, of the routes listed in Figure 2, as a function of the amended link costs.

## DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a communications network KN with four switching nodes $K_i$, 1 <= i <= 4. The switching node $K_1$ is connected to the switching node $K_2$ via a transmission path $U_{12}$, and to the switching node $K_3$ via a transmission path $U_{13}$; the switching node $K_4$ is connected to the switching node $K_2$ via a transmission path $U_{24}$, and the switching node $K_3$ via a transmission path $U_{34}$; a transmission path $U_{14}$, which is represented by a dotted line in the drawing, is also provided between the switching nodes $K_1$ and $K_4$. This is intended to indicate that transmission paths U, for example, the transmission path $U_{14}$, can be temporarily overloaded and/or interrupted. Each of the switching nodes $K_i$ has associated routing information RINF ($K_i$). An arrow pointing to the switching node $K_1$ also indicates that a request VA for a connection V to a connection destination VZ, for example the switching node $K_4$, is transmitted to this switching node $K_1$.

Figure 2 shows the routing information RINF ($K_1$) associated with the switching node $K_1$. This contains, for example, the routes $R_{1j}$ which lead from the switching node $K_1$ to the switching nodes $K_j$, 2 <= j <= 4, and their route cost RK ($R_{1j}$). The routes $R_{1j}$ are in this case defined as one of possibly a number of different options for passing from the switching node $K_1$, including the transmission nodes $K_j$, 2 <= j <= 4 and the transmission paths U, to the switching destination VZ, in the example, the switching node $K_4$. In the example, including the optional transmission path $U_{14}$, three routes $R_{1j-k,}$ 1 <= k <=3 in each case pass from the switching node $K_1$ to the switching nodes $K_j$, to be precise originating from the switching node $K_1$, on the route $R_{12-1}$ directly to the switching node $K_2$, on the route $R_{12-2}$ via the switching nodes $K_3$ and $K_4$ to the switching node $K_2$, and on the route $R_{12-3}$ via the switching node $K_4$ to the switching node $K_2$; the route $R_{13-1}$ via the switching nodes $K_2$ and $K_4$, the route $R_{13-2}$ directly and the route $R_{13-3}$ via the switching node $K_4$ to the switching node $K_3$; the route $R_{14-1}$ via the switching node $K_2$, the route $R_{14-2}$ via the switching node $K_3$, and the route $R_{14-2}$ directly to the switching node $K_4$. The route costs RK ($R_{1j-k}$) of the route $R_{1j-k}$ are, in each case, obtained from the sum of the amended link costs L for each of the transmission paths U used by the routes. In this example, for simplicity reasons, it is assumed that all the transmission paths U are bi-directional and that the link costs LK are independent of the direction of the connection.

Figure 3a shows how link cost LK assigned to the transmission paths U can be used to form amended link costs L as a function of randomly selected numbers EPS. By way of example, let us assume that the link costs LK ($U_{ij}$) = 1, the number EPS ($U_{12}$) = 0.003, the number EPS ($U_{13}$) = 0.005, the number EPS ($U_{14}$) = 0.012, the number EPS ($U_{24}$) = 0,002, the number EPS ($U_{34}$) = 0.007 and the amended link costs L ($U_{ij}$) = LK ($U_{ij}$) + EPS ($U_{ij}$) are defined for the transmission paths $U_{ij}$, ij = 12, 13, 14, 24, 34. It should be noted that the term "link costs" should not be interpreted literally in the sense of "costs". Any desired values which are relevant for the transmission paths may be used for the link costs LK, such as traffic levels or Quality of Service values. By choosing all the link costs LK to be equal to 1, and when using a Dijkstra algorithm, the routes which have optimum route costs RK are those whose connection destination VZ is reached via as few switching nodes K as possible; such optimization metrics are also referred to as "least hops" in the specialist world. The preferred routes R are thus those which reach their connection destination VZ with the shortest delay times, since the total delay time in a route R is normally governed, primarily, by the sum of the delay times for passing through the switching nodes K, provided the transmission paths U are terrestrial, and do pass via satellites. The maximum absolute magnitude of the numbers EPS ($U_{ij}$), which is 0.012, is so small that the amended link costs do not differ significantly from the link costs LK so that the least hops metrics are still valid when carrying out the method according to the present invention.

Figure 3b lists the route costs RK for the routes $R_{1j\text{-}k}$ listed in Figure 2, which have been determined in accordance with the formula quoted in Figure 2 for determining the route costs RK, based on the amended link costs quoted in Figure 3a. If the optional transmission path $U_{14}$ is ignored, the route $R_{14\text{-}1}$ is the optimum route RMIN with the lowest route costs RK of all the routes R. The route $R_{14\text{-}1}$ is at the same time the optimum connection route RMIN(V) for the requested connection V to the switching node $K_4$ since, although it has the same number of hops as the route $R_{14\text{-}2}$, its route costs RK are marginally lower. Taking account of the optional transmission path $U_{14}$, the route $R_{12\text{-}1}$ is the optimum route RMIN, with the lowest route costs RK of all the routes R. In this case, the route $R_{14\text{-}3}$ is the optimum-connection route RMIN(V) for the requested connection V to the

switching node $K_4$, since it has one hop fewer than the routes $R_{14-1}$ and $R_{14-2}$, that is to say the number EPS ($U_{14}$) which is relevant to the route $R_{14-3}$ admittedly has by far the greatest absolute value compared to all the numbers EPS, but this does not substantially change the link costs LK, so that the least hops optimization metrics are still valid.

For the exemplary embodiment, it is assumed that switching node $K_1$ originates a request VA to set up a connection V to the connection destination VZ. This connection destination VZ is assumed to be the switching node $K_4$, and the connection V is thus assumed to be the connection $V_{14}$. In order to restrict the search area, the switching node $K_1$ assesses only those routes R ($V_{14}$) which are relevant for this connection $V_{14}$, that is to say the routes $R_{14-1}$, $R_{14-2}$ and $R_{14-3}$. The numbers EPS are formed for these routes by using a random number generator, and the amended link costs L are then formed. These amended link costs L are used as the basis for a program, for example, which carries out the deterministic Dijkstra algorithm to determine the optimum-connection route RMIN ($V_{14}$), that is to say the route $R_{14-3}$, when the possibly overloaded and/or interrupted transmission path $U_{14}$ is taken into account, otherwise the route $R_{14-1}$. If the state of the transmission path $U_{14}$ is known, for example by the state being reported in the network via a flooding method, this is considered, for example, by excluding the transmission path $U_{14}$ from the routing process for the duration of the overloading and/or interruption; for example, by assigning it very high link costs LK in comparison to the link costs LK of the transmission paths U which are not overloaded and/or interrupted. Following the routing process, the requested connection $V_{14}$ is set up along the optimum-connection route RMIN ($V_{14}$).

Particularly noted advantages are claimed when using the present invention in connection-oriented networks with source routing; for example, ATM networks. In networks such as these, a largely uniform distribution of requested connections over a number of optimum-connection routes RMIN (V) can be achieved, for example, statistically on average, provided the numbers EPS are formed once again regularly; for example, for each requested connection V. If the numbers EPS are in this case formed, for example, using a random number generator, this results in different route costs RK for the relevant routes R (V) on each occasion. In the exemplary embodiment, the routes $R_{14-1}$ and $R_{14-2}$ have the route costs RK ($R_{14-1}$) =

2.005 and RK ($R_{14-2}$) = 2.019. The route costs for the next requested connection $V_{14}$ could be, for example, RK ($R_{14-1}$) = 2.023 and RK ($R_{14-2}$) = 2.004, with the route $R_{14-2}$ in consequence being determined as the optimum-connection route RMIN ($V_{14}$). If the link costs LK were not amended, both routes $R_{14-1}$, $R_{14-2}$ would have identical route costs RK ($R_{14-1}$) = RK ($R_{14-2}$) = 2. In this case, owing to the deterministic behavior of the routing algorithm, the same optimum-connection route RMIN ($V_{14}$) would be determined for each requested connection V; for example, the route $R_{14-1}$ No connections would be set up along the route $R_{14-2}$ until the route $R_{14-1}$ was completely full. A major advantage of this largely uniform distribution is that, on average, it results in the rejection probability for a number of connections, whose requested data rate generally varies randomly, being reduced significantly. The rejection probability is advantageously reduced even further by using a flooding method, for example the PNNI method, in the network, in order to exclude overloaded and/or interrupted transmission paths from routing, at least during the time period when the route is overloaded and/or interrupted.

The present invention also can, of course, be applied to any desired communications networks KN, in particular connectionless communications networks KN such as the packet-oriented Internet. In the Internet, for example, each individual packet is transmitted along a packet-specific route R, that is to say each packet's route in a virtual connection V is independent of the routes R of the previous and subsequent packets within the same virtual connection V; the switching nodes K which, for example, are in the form of Internet Routers, in this case respectively determine only the next switching node K for each packet in a virtual connection V, referred to as a "hop" in the specialist world. In accordance with the method of the present invention, each router distributes possibly successive packets, which are associated with the same virtual connection V, over a number of transmission paths U. The transmission paths U which are connected to one router are, in this case, advantageously uniformly loaded, on average. In this case, for example, different delay times for the individual packets can lead to changes in the original sequence of the packets. As such, the original sequence of the packets in the virtual connection V is reproduced in the receiver using a higher protocol layer.

A number of methods are known for this, for example the Transport Control Protocol TCP.

Indeed, although the present invention has been described with reference to specific embodiments, those of skill in the art, will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.

ABSTRACT OF THE DISCLOSURE

In order to assess routes in a communications network having switching nodes and transmission paths, the link costs assigned to the transmission paths are used, preferably with the aid of random numbers to form amended link costs, and the routes are assessed as a function of the amended link costs. If the amended link costs are formed for every connection request, connections which can be set up along a number of routes with the same minimum route costs are distributed uniformly between these routes while retaining existing routing algorithms.

**In the claims**:

On page 15, cancel line 1, and substitute the following left-hand justified heading therefore.

CLAIMS

Please cancel claims 1-9 without prejudice and substitute the following claims therefor:

10. A method for assessing routes in a communications network which includes switching nodes and transmission paths, the method comprising the steps of:

assigning link costs to the transmission paths;

forming amended link costs using the link costs; and

assessing the routes as a function of the amended link costs.

11. A method for assessing routes in a communications network as claimed in claim 10, wherein the step of forming the amended link costs includes adding randomly selected real numbers to the link costs, with an absolute magnitude of the real numbers being less than a maximum number, which is selected to be sufficiently small that the link costs are not substantially changed.

12. A method for assessing routes in a communications network as claimed in claim 10, the method further comprising the step of:

determining an optimum route defined as a function of the amended link costs via a deterministic routing algorithm.

13. A method for assessing routes in a communications network as claimed in claim 12, wherein the deterministic routing algorithm is a Dijkstra algorithm.

14. A method for assessing routes in a communications network as claimed in claim 10, wherein the communications network assesses relevant routes only for one requested connection.

15. A method for assessing routes in a communications network as claimed in claim 14, wherein the routes are assessed for each request for a connection.

16. A method for assessing routes in a communications network as claimed in claim 15, the method further comprising the step of:

setting up a requested connection in the communications network along a route which is optimum for the requested connection.

17. A method for assessing routes in a communications network as claimed in claim 16, the method further comprising the step of:

determining the route which is optimum for the requested connection by the switching node which processes the request for the connection.

18. A method for assessing routes in a communications network as claimed in claim 17, the method further comprising the step of:

reporting the optimum route for the requested connection to all the switching nodes along the optimum route for the requested connection while the requested connection is set up.

## REMARKS

The present amendment makes editorial changes and corrects typographical errors in the specification, which includes the Abstract, in order to conform the specification to the requirements of United States Patent Practice. No new matter is added thereby. Attached hereto is a marked-up version of the changes made to the specification by the present amendment. The attached page is captioned "**<u>Version With Markings To Show Changes Made</u>**".

In addition, the present amendment cancels original claims 1-9 in favor of new claims 10-18. Claims 10-18 have been presented solely because the revisions by red-lining and underlining which would have been necessary in claims 1-9 in order to present those claims in accordance with preferred United States Patent Practice would have been too extensive, and thus would have been too burdensome. The present amendment is intended for clarification purposes only and not for substantial reasons related to patentability pursuant to 35 U.S.C. §§103, 102, 103 or 112. Indeed, the cancellation of claims 1-9 does not constitute an intent on the part of the Applicants to surrender any of the subject matter of claims 1-9.

Early consideration on the merits is respectfully requested.

Respectfully submitted,

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## VERSION WITH MARKINGS TO SHOW CHANGES MADE

**In The Specification:**

The Specification of the present application, including the Abstract, has been amended as follows:

SPECIFICATION

TITLE OF INVENTION ~~Description~~

METHOD FOR ASSESSMENT OF ROUTES IN A COMMUNICATIONS NETWORK

BACKGROUND OF THE INVENTION

Communications networks are normally either in the form of packet-oriented networks or line-oriented networks. In this case, packet-oriented networks are more suitable for transmitting information without any real-time nature, such as data, e-mails or files, while line-oriented networks are highly suitable for transmitting information with a real-time nature, such as voice or moving images. However, as line-oriented and packet-oriented networks converge, voice and moving-image information is also increasingly being transmitted in packet-oriented networks. Examples of packet-oriented networks are the Internet or ATM (= Asynchronous Transfer Mode) with the expression ATM also occasionally being used as a synonym for B-ISDN (= Broadband Integrated Services Digital Network). The packet-oriented network technology will be explained in more detail in the following text using the example of ATM.

A characteristic feature of packet-oriented networks is the packet-oriented transmission of information. In ATM networks, the information is ~~in this case~~, for example, split into packets of equal length - also referred to as "ATM cells" - which have a cell-header ~~comprising~~ including 5 bytes, and an information section (payload) ~~comprising~~ including 48 bytes. In this case, the individual cells are allocated by the cell headers to specific information streams - also referred to as "virtual connections". In contrast to, for example, a line-oriented TDMA method, in which timeslots are allocated from the start to different types of data traffic, the information streams that arrive at an ATM interface are segmented into the said 53-byte cells, and these cells are then sent onward sequentially in the sequence in which they were produced. The multiplexing method used for TDMA is also

referred to as “static multiplexing”, while that used for ATM is referred to as “statistical multiplexing”. Owing to the flexibility of statistical multiplexing, the information streams in the case of ATM may have any desired data rates, while the data rate for the individual information streams - also referred to as “connections” - when using static multiplexing is fixed-, for example, at 64 kbps in the case of ISDN, —owing to the fixed association between the timeslots and the information streams.

As a consequence of this difference, the routing of a requested connection in packet-oriented networks is dependent on the available capacity remaining on a route while, in line-oriented networks, it is in principle independent of the load level of the individual transmission paths. For example, on a route in a line-oriented network along which, for example, 30 connections can be carried, using a TDM method, in fixed allocated timeslots each having a capacity of 64 kbps, a further connection ~~can~~ also ~~invariably~~ can be set up when 29 connections ~~have~~ already have been set up, since the further connection does not require a higher data rate than the remaining capacity of 64 kbps that is still available, since its data rate is constant. However, only connections for which a data rate of less than 30 Mbps has been requested can be set up along a route in a packet-oriented network with an assumed remaining capacity of 30 Mbps. Connections with a higher data rate are, however, rejected. If any alternative routes exist, they can be set up by way of a substitute along an alternative route with sufficient remaining capacity. However, renewed routing is required in order to determine an alternative route.

Various routing methods are known by ~~means of~~ which it is possible to determine routes in networks. One option is referred to as “source routing”, in which the complete route to a destination switching node is determined, starting from an initial switching node. For ATM networks, for example, the ATM forum has demanded source routing for the purposes of the PNNI (= Private Network-Network Interface) Specification. In this case, the route is determined by the initial switching node and then, when setting up the connection, the calculated route is transmitted to the switching nodes along the route~~,~~ by signaling. A further option is referred to as “Hop-by-Hop routing” in which each switching node along a route recalculates the rest of the route, or the next section of the route. This method is used, for example, in the Internet or in ATM networks without source routing.

What are referred to as flooding methods have been proposed in order to exclude from the routing process those routes which use overloaded or interrupted transmission paths. In this case, all the switching nodes measure the traffic levels of the transmission paths connected to them at defined times, and pass this information on to all the other switching nodes within a group. This passing on of information is referred to as "flooding". Flooding ~~can additionally~~ also <u>can</u> be carried out when the traffic levels on the transmission paths change significantly~~.~~; for example, when the actual load level on a transmission path with a total capacity of 150 Mbps differs by more than 10 Mbps from the last load level passed on. For example, the PNNI Specification proposes that methods be used in ATM networks which provide a routing algorithm with the respective traffic levels measured most recently in the switching nodes in the ATM network for those transmission paths which are directly connected to them. In the context of PNNI, reference <u>also</u> should ~~also~~ be made to U. Gremmelmaier, J. Püschner, M. Winter and P. Jocher, "Performance Evaluation of the PNNI Routing Protocol using an Emulation Tool", ISS 97 XVI World Telecom Congress Proceedings, pp 401 - 408.

Routing in line-oriented, public telephone networks is known. In this case, the routing process is normally carried out in a number of steps, since these networks are normally hierarchically constructed since there are generally a large number of switching nodes. In a first step, connections in these networks are routed from an initial switching node on a lower hierarchical level to a switching node on the uppermost hierarchical level and then, in a second step, they are routed within the uppermost hierarchy level to a switching node which represents the connection destination before, finally, being routed in a third step to the destination switching node in a lower hierarchy level. In this case, the first and third steps generally make use of fixed selected routes or, for example if these are interrupted, fixed set alternative routes, while the second step frequently requires only a selection of the transmission path between the two affected switching nodes in the uppermost hierarchy level, since the switching nodes in the uppermost level are virtually completely networked with one another. However, Signaling procedure No. 7, which has been standardized for line-oriented telephone networks, does not support source routing~~,~~; that is ~~to say~~, the initial switching node cannot pass on a route which it calculated. In consequence, the switching nodes along the route do

not know the route that ~~has~~ already has been traveled over either, so that, when using this routing method, it is possible for loops to occur in the routes in network, for example the Internet, which are not hierarchically structured and/or are only partially networked.

German Patent DE 441356 discloses a dynamic routing method for routing in packet-oriented networks, in which blockages in transmission paths are detected, and the load level on the transmission paths is determined from the frequency of these blockages. The probability of the transmission paths being occupied can be calculated off-line, from destination traffic data, ~~by~~ through the use of a routing management processor. The "Forward Looking Routing" algorithm as defined by K.R. Krishnan, T.J. Ott in Forward-Looking Routing, A New State-Dependent Routing Scheme, Teletraffic Science for New Cost-Effective Systems, Networks and Services, ITC-12 (1989) is suitable, for example, for such a calculation. However, this method considers only connections with an identical, constant bandwidth, such as those which are typical for conventional telephone connections in line-switching networks;~~,~~ that is to say, the bandwidth for one connection is, for example, 64 kbps. For packet-oriented networks such as ATM networks (Asynchronous Transfer Mode), on the other hand, a constant bit rate is an exceptional situation, since connections can be made in accordance with the subscribers' connection requirements with different bandwidths~~,~~ which can vary with time. In addition to the desired bandwidth, for example 1 Mbps, connection requests from subscribers often also contain information relating to the required connection quality.

The present invention ~~is based on the object of~~, therefore, is directed toward improving the routing for packet-oriented communications networks. ~~The object is achieved by the features of patent claim 1.~~

SUMMARY OF THE INVENTION

~~The~~ A major aspect of the present invention is the assessment of routes in a communications network which ~~comprises~~ includes switching nodes and transmission paths and is, in particular, packet-oriented and possible connection-oriented, and in which link costs which are assigned to the transmission paths are used to form amended link costs, and the routes are assessed as a function of the amended link costs. ~~The~~ A major advantage of the present invention is that

different assessments of the routes can be obtained by different amendments to the originally assigned link costs. It is thus advantageously possible to control the assessments of the routes by the nature of the amendments to the original link cost~~,~~; that is ~~to say~~, without changing the assessment itself.

According to one ~~refinement~~ embodiment of the method according to the present invention, the amended link costs are intended to be formed by addition of randomly selected real numbers to the link costs, with the absolute magnitude of the real numbers being less than a maximum number, which is selected to be sufficiently small that the link costs are not substantially changed~~—claim 2~~. This advantageously generally results in minimally different route costs for routes which would have identical route costs if the original link costs had not been amended. However, a route with significantly higher route costs than the optimum route costs has an optimum route, even if the original link costs are amended, ~~[lacuna]~~ it has considerably higher route costs than the optimum route costs then determined. Minimal differentiation between the route costs is thus advantageously achieved only within a group of routes whose route costs with unamended link costs are identical, while the allocation of the routes to such groups of routes with the same route costs, and the sequence of the groups themselves, remain unchanged.

According to one ~~development~~ embodiment of the method according to the present invention, an optimum route, which is defined as a function of the amended link costs, is determined ~~by means of~~ via a deterministic routing algorithm~~—claim 3~~. This has the advantage that a deterministic routing algorithm is, in general, less complex than a non-deterministic routing algorithm~~,~~ and ~~can~~ thus can be processed more efficiently.

According to ~~one refinement~~ another embodiment of the method according to the present invention, the deterministic routing algorithm is in the form of a Dijkstra algorithm~~—claim 4~~. Proven standard software ~~can~~, thus ~~advantageously~~ can be used, since the Dijkstra algorithm has actually been known since 1959, and highly efficient and technically proven implementations are available. The optimum route also ~~advantageously~~ has minimum route costs.

According to one ~~variant~~ embodiment of the method according to the present invention, the communications network assesses relevant routes only for one requested connection~~—claim 5~~. This advantageously reduces the number of

routes to be assessed and, in consequence, the processing time for assessment of the routes.

According to ~~one development~~ a further embodiment of the method according to the present invention, the routes are assessed for each request for a connection~~—claim 6~~. The amendment of the link costs, in particular the random selection of the real numbers, advantageously ~~means that~~ allows for, if there are a number of optimum routes which would have identical minimum route costs if the link costs were not amended, one of these routes ~~is~~ to be optionally selected on the requested connection for each connection request, even though a deterministic routing algorithm, that is to say a routing algorithm which determines the same optimum route without amending the link costs in each case, is used to select the route that is optimum for the connection. This ~~advantageously~~ considerably reduces the statistically average probability of blocking~~,~~ since the load levels on the transmission paths are more uniform than if the connections were all set up along the same route.

According to one application of the method according to the present invention to a method for setting up a connection in a communications network which ~~comprises~~ includes switching nodes and transmission paths, the connection is set up along a route which is optimum for this connection~~—claim 7~~. The assessment of the routes is thus advantageously used for the selection of a route. In particular, the randomly controlled amendment of the link costs when there are a number of comparable routes leaves the question open as to which of the routes is optimum for that connection. The connections are not, therefore ~~not~~, automatically set up via the same route, with the load being shared between equivalent routes. This considerably reduces the blocking rates for connections.

According to ~~one refinement~~ embodiment of the application of the method according to the present invention, the route which is optimum for the connection is determined by that switching node which processes the request for the connection~~—claim 8~~. This has the advantage that the request can be processed very efficiently, since no messages are required between the node processing request and a further node carrying out the routing.

According to ~~one development~~ another embodiment of the application of the method according to the present invention, the optimum route for the requested

connection is reported to all the switching nodes along the optimum route for the requested connection while the connection is being set up~~—claim 9~~. The present invention can, thus ~~advantageously,~~ be used in networks with source routing.

~~The method according to the invention will be explained in more detail in the following text with reference to a number of figures, in which:~~

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

## BRIEF DESCRIPTION OF THE FIGURES

Figure 1 uses a block diagram to show a communications network with switching nodes and transmission paths~~,~~.

Figure 2 uses a table to show all the routes which originate from the switching node $K_1$ to the other switching nodes in the communications network illustrated in Figure 1~~,~~.

Figure 3a uses a table to show the formation, according to the present invention, of amended link costs from link costs assigned to the transmission paths~~,~~ ~~and~~.

Figure 3b uses a table to show the assessment, according to the present invention, of the routes listed in Figure 2, as a function of the amended link costs.

## DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a communications network KN with four switching nodes $K_i$, $1 <= i <= 4$. The switching node $K_1$ is connected to the switching node $K_2$ ~~by means of~~ via a transmission path $U_{12}$, and to the switching node $K_3$ ~~by means of~~ via a transmission path $U_{13}$; the switching node $K_4$ is connected to the switching node $K_2$ ~~by means of~~ via a transmission path $U_{24}$, and the switching node $K_3$ ~~by means of~~ via a transmission path $U_{34}$; a transmission path $U_{14}$, which is represented by a dotted line in the drawing, is also provided between the switching nodes $K_1$ and $K_4$. This is intended to indicate that transmission paths U~~-~~, for example, the transmission path $U_{14}$~~-~~, can be temporarily overloaded and/or interrupted. Each of the switching nodes $K_i$ has associated routing information RINF ($K_i$). An arrow pointing to the switching node $K_1$ also indicates that a request VA for a connection V to a connection destination VZ~~-~~, for example the switching node $K_4$~~-~~, is transmitted to this switching node $K_1$.

Figure 2 shows the routing information RINF ($K_1$) associated with the switching node $K_1$. This contains, for example, the routes $R_{1j}$ which lead from the switching node $K_1$ to the switching nodes $K_j$, $2 <= j <= 4$, and their route cost RK ($R_{1j}$). The routes $R_{1j}$ are in this case defined as one of possibly a number of different options for passing from the switching node $K_1$, including the transmission nodes $K_j$, $2 <= j <= 4$ and the transmission paths U, to the switching destination VZ-, in the example, the switching node $K_4$. In the example, including the optional transmission path $U_{14}$, three routes $R_{1j-k,}$ $1 <= k <=3$ in each case pass from the switching node $K_1$ to the switching nodes $K_j$, to be precise originating from the switching node $K_1$, on the route $R_{12-1}$ directly to the switching node $K_2$, on the route $R_{12-2}$ via the switching nodes $K_3$ and $K_4$ to the switching node $K_2$, and on the route $R_{12-3}$ via the switching node $K_4$ to the switching node $K_2$; the route $R_{13-1}$ via the switching nodes $K_2$ and $K_4$, the route $R_{13-2}$ directly and the route $R_{13-3}$ via the switching node $K_4$ to the switching node $K_3$; the route $R_{14-1}$ via the switching node $K_2$, the route $R_{14-2}$ via the switching node $K_3$, and the route $R_{14-2}$ directly to the switching node $K_4$. The route costs RK ($R_{1j-k}$) of the route $R_{1j-k}$ are, in each case, obtained from the sum of the amended link costs L for each of the transmission paths U used by the routes. In this example, for simplicity ~~reason~~ reasons, it is assumed that all the transmission paths U are bi-directional and that the link costs LK are independent of the direction of the connection.

Figure 3a shows how link cost LK assigned to the transmission paths U can be used to form amended link costs L as a function of randomly selected numbers EPS. By way of example, let us assume that the link costs LK ($U_{ij}$) = 1, the number EPS ($U_{12}$) = 0.003, the number EPS ($U_{13}$) = 0.005, the number EPS ($U_{14}$) = 0.012, the number EPS ($U_{24}$) = 0,002, the number EPS ($U_{34}$) = 0.007 and the amended link costs L ($U_{ij}$) = LK ($U_{ij}$) + EPS ($U_{ij}$) are defined for the transmission paths $U_{ij}$, ij = 12, 13, 14, 24, 34. It should be noted that the term "link costs" should not be interpreted literally in the sense of "costs". Any desired values which are relevant for the transmission paths may be used for ~~form~~ the link costs LK, such as traffic levels or Quality of Service values. By choosing all the link costs LK to be equal to 1, and when using a Dijkstra algorithm, the routes which have optimum route costs RK are those whose connection destination VZ is reached via as few switching nodes K as possible-; such optimization metrics are

also referred to as "least hops" in the specialist world. The preferred routes R are thus those which reach their connection destination VZ with the shortest delay times, since the total delay time in a route R is normally governed ~~essentially,~~ primarily, by the sum of the delay times for passing through the switching nodes K, provided the transmission paths U are terrestrial, and do pass via satellites. The maximum absolute magnitude of the numbers EPS ($U_{ij}$), which is 0.012, is so small that the amended link costs do not differ significantly from the link costs LK so that the least hops metrics are still valid when carrying out the method according to the present invention.

Figure 3b lists the route costs RK for the routes $R_{1j\text{-}k}$ listed in Figure 2, which have been determined in accordance with the formula quoted in Figure 2 for determining the route costs RK, based on the amended link costs quoted in Figure 3a. If the optional transmission path $U_{14}$ is ignored, the route $R_{14\text{-}1}$ is the optimum route RMIN with the lowest route costs RK of all the routes R. The route $R_{14\text{-}1}$ is at the same time the optimum connection route RMIN(V) for the requested connection V to the switching node $K_4$ since, although it has the same number of hops as the route $R_{14\text{-}2}$, its route costs RK are~~, however,~~ marginally lower. Taking account of the optional transmission path $U_{14}$, the route $R_{12\text{-}1}$ is the optimum route RMIN, with the lowest route costs RK of all the routes R. In this case, the route $R_{14\text{-}3}$ is the optimum-connection route RMIN(V) for the requested connection V to the switching node $K_4$, since it has one hop fewer than the routes $R_{14\text{-}1}$ and $R_{14\text{-}2}$, that is to say the number EPS ($U_{14}$) which is relevant to the route $R_{14\text{-}3}$ admittedly has by far the greatest absolute value compared to all the numbers EPS, but this does not substantially change the link costs LK, so that the least hops optimization metrics are still valid.

For the exemplary embodiment, it is assumed that switching node $K_1$ originates a request VA to set up a connection V to the connection destination VZ. This connection destination VZ is assumed to be the switching node $K_4$, and the connection V is thus assumed to be the connection $V_{14}$. In order to restrict the search area, the switching node $K_1$ assesses only those routes R ($V_{14}$) which are relevant for this connection $V_{14}$, that is to say the routes $R_{14\text{-}1}$, $R_{14\text{-}2}$ and $R_{14\text{-}3}$. The numbers EPS are formed for these routes by using a random number generator, and the amended link costs L are then formed. These amended link costs L are used~~,~~ as

the basis for a program, for example, which carries out the deterministic Dijkstra algorithm to determine the optimum-connection route RMIN ($V_{14}$), that is to say the route $R_{14-3}$, when the possibly overloaded and/or interrupted transmission path $U_{14}$ is taken into account, otherwise the route $R_{14-1}$. If the state of the transmission path $U_{14}$ is known, for example by the state being reported in the network ~~by means of~~ via a flooding method, this is considered, for example, by excluding the transmission path $U_{14}$ from the routing process for the duration of the overloading and/or interruption;~~,~~ for example by assigning it very high link costs LK in comparison to the link costs LK of the transmission paths U which are not overloaded and/or interrupted. Following the routing process, the requested connection $V_{14}$ is set up along the optimum-connection route RMIN ($V_{14}$).

Particularly noted advantages are claimed when using the present invention in connection-oriented networks with source routing~~,~~; for example, ATM networks. In networks such as these, a largely uniform distribution of requested connections over a number of optimum-connection routes RMIN (V) can be achieved, for example, statistically on average, provided the numbers EPS are formed once again regularly;~~,~~ for example, for each requested connection V. If the numbers EPS are in this case formed, for example, using a random number generator, this ~~therefore~~ results in different route costs RK for the relevant routes R (V) on each occasion. In the exemplary embodiment, the routes $R_{14-1}$ and $R_{14-2}$ have the route costs RK ($R_{14-1}$) = 2.005 and RK ($R_{14-2}$) = 2.019. The route costs for the next requested connection $V_{14}$ could be, for example, RK ($R_{14-1}$) = 2.023 and RK ($R_{14-2}$) = 2.004, with the route $R_{14-2}$ in consequence being determined as the optimum-connection route RMIN ($V_{14}$). If the link costs LK were not amended, both routes $R_{14-1}$, $R_{14-2}$ would have identical route costs RK ($R_{14-1}$) = RK ($R_{14-2}$) = 2. In this case, owing to the deterministic behavior of the routing algorithm, the same optimum-connection route RMIN ($V_{14}$) would be determined for each requested connection V;~~,~~ for example, the route $R_{14-1}$ No connections would be set up along the route $R_{14-2}$ until the route $R_{14-1}$ was completely full. A major advantage of this largely uniform distribution is that, on average, it results in the rejection probability for a number of connections, whose requested data rate generally varies randomly, being reduced significantly. The rejection probability is advantageously reduced even further by using a flooding method, for example the PNNI method, in the network, in order to

exclude overloaded and/or interrupted transmission paths from routing, at least during the time period when the route is overloaded and/or interrupted.

~~It should be mentioned that the~~ The present invention also can, of course, ~~also~~ be applied to any desired communications networks KN, in particular connectionless communications networks KN such as the packet-oriented Internet. In the Internet, for example, each individual packet is transmitted along a packet-specific route R, that is to say each packet's route in a virtual connection V is independent of the routes R of the previous and subsequent packets within the same virtual connection V; the switching nodes K~~,~~ which, for example, are in the form of Internet Routers, in this case ~~in each case~~ respectively determine only the next switching node K for each packet in a virtual connection V~~.~~, referred to as a "hop" in the specialist world. In accordance with the method ~~according to~~ of the present invention, each router distributes possibly successive packets, which are associated with the same virtual connection V, over a number of transmission paths U. The transmission paths U which are connected to one router are, in this case, advantageously uniformly loaded, on average. In this case, for example, different delay times for the individual packets can lead to changes in the original sequence of the packets. ~~In this case~~ As such, the original sequence of the packets in the virtual connection V is reproduced in the receiver using a higher protocol layer.

A number of methods are known for this, for example the Transport Control Protocol TCP.

~~It should be understood that various changes and modifications to the presently preferred embodiments described herein will be apparent to those skilled in the art. Such changes and modifications can be made~~ Indeed, although the present invention has been described with reference to specific embodiments, those of skill in the art, will recognize that changes may be made thereto without departing from the spirit and scope of the ~~present invention and without diminishing its intended advantages. It is therefore intended that such changes and modifications be covered by the appended claims.~~ invention as set forth in the hereafter appended claims.

~~Abstract~~

~~Method for assessment of routes in a communications network~~ ABSTRACT OF THE DISCLOSURE

In order to assess routes ~~R~~ in a communications network ~~KN comprising~~ having switching nodes ~~K~~ and transmission paths ~~U~~, the link costs ~~LK~~ assigned to the transmission paths ~~U~~ are used-, preferably with the aid of random numbers -to form amended link costs ~~L~~, and the routes ~~R~~ are assessed as a function of the amended link costs ~~L~~. If the amended link costs ~~L~~ are formed for every connection request, connections ~~V~~ which can be set up along a number of routes ~~R~~ with the same minimum route costs ~~RK~~ are distributed uniformly between these routes ~~R~~ while retaining existing routing algorithms.

~~Figure 2~~

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Description

Method for assessment of routes in a communications network

Communications networks are normally either in the form of packet-oriented networks or line-oriented networks. In this case, packet-oriented networks are more suitable for transmitting information without any real-time nature, such as data, e-mails or files, while line-oriented networks are highly suitable for transmitting information with a real-time nature, such as voice or moving images. However, as line-oriented and packet-oriented networks converge, voice and moving-image information is also increasingly being transmitted in packet-oriented networks. Examples of packet-oriented networks are the Internet or ATM (= Asynchronous Transfer Mode) with the expression ATM also occasionally being used as a synonym for B-ISDN (= Broadband Integrated Services Digital Network). The packet-oriented network technology will be explained in more detail in the following text using the example of ATM.

A characteristic feature of packet-oriented networks is the packet-oriented transmission of information. In ATM networks, the information is in this case, for example, split into packets of equal length - also referred to as "ATM cells" - which have a cell-header comprising 5 bytes, and an information section (payload) comprising 48 bytes. In this case, the individual cells are allocated by the cell headers to specific information streams - also referred to as "virtual connections". In contrast to, for example, a line-oriented TDMA method, in which timeslots are allocated from the start to different types of data traffic, the information

streams that arrive at an ATM interface are segmented into the said 53-byte cells, and these cells are then sent onward sequentially in the sequence

in which they were produced. The multiplexing method used for TDMA is also referred to as "static multiplexing", while that used for ATM is referred to as "statistical multiplexing". Owing to the flexibility of statistical multiplexing, the information streams in the case of ATM may have any desired data rates, while the data rate for the individual information streams - also referred to as "connections" - when using static multiplexing is fixed - for example at 64 kbps in the case of ISDN - owing to the fixed association between the timeslots and the information streams.

As a consequence of this difference, the routing of a requested connection in packet-oriented networks is dependent on the available capacity remaining on a route while, in line-oriented networks, it is in principle independent of the load level of the individual transmission paths. For example, on a route in a line-oriented network along which, for example, 30 connections can be carried, using a TDM method, in fixed allocated timeslots each having a capacity of 64 kbps, a further connection can also invariably be set up when 29 connections have already been set up, since the further connection does not require a higher data rate than the remaining capacity of 64 kbps that is still available, since its data rate is constant. However, only connections for which a data rate of less than 30 Mbps has been requested can be set up along a route in a packet-oriented network with an assumed remaining capacity of 30 Mbps. Connections with a higher data rate are, however, rejected. If any alternative routes exist, they can be set up by way of a substitute along an alternative route with sufficient remaining capacity. However, renewed routing is required in order to determine an alternative route.

Various routing methods are known by means of which it is possible to determine routes in networks. One option

is referred to as "source routing", in which the complete route

to a destination switching node is determined, starting from an initial switching node. For ATM networks, for example, the ATM forum has demanded source routing for the purposes of the PNNI (= Private Network-Network Interface) Specification. In this case, the route is determined by the initial switching node and then, when setting up the connection, the calculated route is transmitted to the switching nodes along the route, by signaling. A further option is referred to as "Hop-by-Hop routing" in which each switching node along a route recalculates the rest of the route, or the next section of the route. This method is used, for example, in the Internet or in ATM networks without source routing.

What are referred to as flooding methods have been proposed in order to exclude from the routing process those routes which use overloaded or interrupted transmission paths. In this case, all the switching nodes measure the traffic levels of the transmission paths connected to them at defined times, and pass this information on to all the other switching nodes within a group. This passing on of information is referred to as "flooding". Flooding can additionally also be carried out when the traffic levels on the transmission paths change significantly - for example when the actual load level on a transmission path with a total capacity of 150 Mbps differs by more than 10 Mbps from the last load level passed on. For example, the PNNI Specification proposes that methods be used in ATM networks which provide a routing algorithm with the respective traffic levels measured most recently in the switching nodes in the ATM network for those transmission paths which are directly connected to them. In the context of PNNI, reference should also be made to U. Gremmelmaier, J. Püschner, M. Winter and P. Jocher, "Performance Evaluation of the PNNI Routing Protocol using an Emulation Tool", ISS 97 XVI World Telecom Congress Proceedings, pp 401 - 408.

Routing in line-oriented, public telephone networks is known. In this case, the routing process is normally carried out in a number of steps, since these networks are normally hierarchically constructed since there are generally a large number of switching nodes. In a first step, connections in these networks are routed from an initial switching node on a lower hierarchical level to a switching node on the uppermost hierarchical level and then, in a second step, they are routed within the uppermost hierarchy level to a switching node which represents the connection destination before, finally, being routed in a third step to the destination switching node in a lower hierarchy level. In this case, the first and third steps generally make use of fixed selected routes or, for example if these are interrupted, fixed set alternative routes, while the second step frequently requires only a selection of the transmission path between the two affected switching nodes in the uppermost hierarchy level, since the switching nodes in the uppermost level are virtually completely networked with one another. However, Signaling procedure No. 7, which has been standardized for line-oriented telephone networks, does not support source routing, that is to say the initial switching node cannot pass on a route which it calculated. In consequence, the switching nodes along the route do not know the route that has already been traveled over either, so that, when using this routing method, it is possible for loops to occur in the routes in network, for example the Internet, which are not hierarchically structured and/or are only partially networked.

German Patent DE 441356 discloses a dynamic routing method for routing in packet-oriented networks, in which blockages in transmission paths are detected, and

the load level on the transmission paths is determined from the frequency of these blockages. The probability of the transmission paths being occupied can be calculated off-line, from destination traffic data, by the use of a routing management

processor. The "Forward Looking Routing" algorithum as defined by K. R. Krishnan, T. J. Ott in Forward-Looking Routing, A New State-Dependent Routing Scheme, Teletraffic Science for New Cost-Effective Systems, Networks and Services, ITC-12 (1989) is suitable, for example, for such a calculation. However, this method considers only connections with an identical, constant bandwidth, such as those which are typical for conventional telephone connections in line-switching networks, that is to say the bandwidth for one connection is, for example, 64 kbps. For packet-oriented networks such as ATM networks (Asynchronous Transfer Mode), on the other hand, a constant bit rate is an exceptional situation, since connections can be made in accordance with the subscribers' connection requirements with different bandwidths, which can vary with time. In addition to the desired bandwidth, for example 1 Mbps, connection requests from subscribers often also contain information relating to the required connection quality.

The invention is based on the object of improving the routing for packet-oriented communications networks. The object is achieved by the features of patent claim 1.

The major aspect of the invention is the assessment of routes in a communications network which comprises switching nodes and transmission paths and is, in particular, packet-oriented and possible connection-oriented, and in which link costs which are assigned to the transmission paths are used to form amended link costs, and the routes are assessed as a function of the amended link costs. The major advantage of the invention is that different assessments of the routes can be obtained by different amendments to the originally assigned link costs. It is thus advantageously possible to control the assessments of

the routes by the nature of the amendments to the original link cost, that is to say without changing the assessment itself.

According to one refinement of the method according to the invention, the amended link costs are intended to be formed by addition of randomly selected real numbers to the link costs, with the absolute magnitude of the real numbers being less than a maximum number, which is selected to be sufficiently small that the link costs are not substantially changed - claim 2. This advantageously generally results in minimally different route costs for routes which would have identical route costs if the original link costs had not been amended. However, a route with significantly higher route costs than the optimum route costs has an optimum route, even if the original link costs are amended, [lacuna] considerably higher route costs than the optimum route costs then determined. Minimal differentiation between the route costs is thus advantageously achieved only within a group of routes whose route costs with unamended link costs are identical, while the allocation of the routes to such groups of routes with the same route costs, and the sequence of the groups themselves, remain unchanged.

According to one development of the method according to the invention, an optimum route, which is defined as a function of the amended link costs, is determined by means of a deterministic routing algorithm - claim 3. This has the advantage that a deterministic routing algorithm is in general less complex than a non-deterministic routing algorithm, and can thus be processed more efficiently.

According to one refinement of the method according to the invention, the deterministic routing algorithm is in the form of a Dijkstra algorithm - claim 4. Proven standard software can thus advantageously be used, since the Dijkstra algorithm has actually been known

since 1959, and highly efficient and technically proven implementations are available. The optimum route also advantageously has minimum route costs.

According to one variant of the method according to the invention, the communications network assesses relevant routes only for one requested connection - claim 5. This advantageously reduces the number of routes to be assessed and, in consequence, the processing time for assessment of the routes.

According to one development of the method according to the invention, the routes are assessed for each request for a connection - claim 6. The amendment of the link costs, in particular the random selection of the real numbers, advantageously means that, if there are a number of optimum routes which would have identical minimum route costs if the link costs were not amended, one of these routes is optionally selected on the requested connection for each connection request, even though a deterministic routing algorithm, that is to say a routing algorithm which determines the same optimum route without amending the link costs in each case, is used to select the route that is optimum for the connection. This advantageously considerably reduces the statistically average probability of blocking, since the load levels on the transmission paths are more uniform than if the connections were all set up along the same route.

According to one application of the method according to the invention to a method for setting up a connection in a communications network which comprises switching nodes and transmission paths, the connection is set up along a route which is optimum for this connection - claim 7. The assessment of the routes is thus advantageously used for the selection of a route. In particular, the randomly controlled amendment of the link costs when there are a number of comparable routes leaves the question open as to which of the routes is

optimum for that connection. The connections are therefore not automatically set up via the same route, with the load being shared between

equivalent routes. This considerably reduces the blocking rates for connections.

According to one refinement of the application of the method according to the invention the route which is optimum for the connection is determined by that switching node which processes the request for the connection - claim 8. This has the advantage that the request can be processed very efficiently, since no messages are required between the node processing request and a further node carrying out the routing.

According to one development of the application of the method according to the invention, the optimum route for the requested connection is reported to all the switching nodes along the optimum route for the requested connection while the connection is being set up - claim 9. The invention can thus advantageously be used in networks with source routing.

The method according to the invention will be explained in more detail in the following text with reference to a number of figures, in which:

Figure 1 uses a block diagram to show a communications network with switching nodes and transmission paths,

Figure 2 uses a table to show all the routes which originate from the switching node $K_1$ to the other switching nodes in the communications network illustrated in Figure 1,

Figure 3a uses a table to show the formation, according to the invention, of amended link costs from link costs assigned to the transmission paths, and

Figure 3b uses a table to show the assessment, according to the invention, of the routes listed in Figure 2, as a function of the amended link costs.

Figure 1 shows a communications network KN with four switching nodes $K_i$, 1 <= i <= 4. The switching node $K_1$ is connected to the switching node $K_2$ by means of a transmission path $U_{12}$, and to the switching node $K_3$ by means of a transmission path $U_{13}$; the switching node $K_4$ is connected to the switching node $K_2$ by means of a transmission path $U_{24}$, and the switching node $K_3$ by means of a transmission path $U_{34}$; a transmission path $U_{14}$, which is represented by a dotted line in the drawing, is also provided between the switching nodes $K_1$ and $K_4$. This is intended to indicate that transmission paths U - for example the transmission path $U_{14}$ - can be temporarily overloaded and/or interrupted. Each of the switching nodes $K_i$ has associated routing information RINF ($K_i$). An arrow pointing to the switching node $K_1$ also indicates that a request VA for a connection V to a connection destination VZ - for example the switching node $K_4$ - is transmitted to this switching node $K_1$.

Figure 2 shows the routing information RINF ($K_1$) associated with the switching node $K_1$. This contains, for example, the routes $R_{1j}$ which lead from the switching node $K_1$ to the switching nodes $K_j$, 2 <= j <= 4, and their route cost RK ($R_{1j}$). The routes $R_{1j}$ are in this case defined as one of possibly a number of different options for passing from the switching node $K_1$, including the transmission nodes $K_j$, 2 <= j <= 4 and the transmission paths U, to the switching destination VZ - in the example the switching node $K_4$. In the example, including the optional transmission path $U_{14}$, three routes $R_{1j-k}$, 1 <= k <=3 in each case pass from the switching node $K_1$ to the switching nodes $K_j$, to be precise originating from the switching node $K_1$, on the route $R_{12-1}$ directly to the switching node $K_2$, on the route $R_{12-2}$ via the switching nodes $K_3$ and $K_4$ to the

switching node $K_2$, and on the route $R_{12-3}$ via the switching node $K_4$ to the switching node $K_2$; the route $R_{13-1}$ via the switching nodes $K_2$ and $K_4$, the route $R_{13-2}$ directly

and the route $R_{13-3}$ via the switching node $K_4$ to the switching node $K_3$; the route $R_{14-1}$ via the switching node $K_2$, the route $R_{14-2}$ via the switching node $K_3$, and the route $R_{14-2}$ directly to the switching node $K_4$. The route costs RK ($R_{1j-k}$) of the route $R_{1j-k}$ are in each case obtained from the sum of the amended link costs L for each of the transmission paths U used by the routes. In this example, for simplicity reason, it is assumed that all the transmission paths U are bi-directional and that the link costs LK are independent of the direction of the connection.

Figure 3a shows how link cost LK assigned to the transmission paths U can be used to form amended link costs L as a function of randomly selected numbers EPS. By way of example, let us assume that the link costs LK ($U_{ij}$) = 1, the number EPS ($U_{12}$) = 0.003, the number EPS ($U_{13}$) = 0.005, the number EPS ($U_{14}$) = 0.012, the number EPS ($U_{24}$) = 0,002, the number EPS ($U_{34}$) = 0.007 and the amended link costs L ($U_{ij}$) = LK ($U_{ij}$) + EPS ($U_{ij}$) are defined for the transmission paths $U_{ij}$, ij = 12, 13, 14, 24, 34. It should be noted that the term "link costs" should not be interpreted literally in the sense of "costs". Any desired values which are relevant for the transmission paths may be used for form the link costs LK, such as traffic levels or Quality of Service values. By choosing all the link costs LK to be equal to 1, and when using a Dijkstra algorithm, the routes which have optimum route costs RK are those whose connection destination VZ is reached via as few switching nodes K as possible - such optimization metrics are also referred to as "least hops" in the specialist world. The preferred routes R are thus those which reach their connection destination VZ with the shortest delay times, since the total delay time in a route R is normally governed essentially by the sum of

the delay times for passing through the switching nodes K, provided the transmission paths U are terrestrial, and do pass via satellites. The maximum absolute magnitude of the numbers EPS $(U_{ij})$, which is 0.012, is so small that the amended

link costs do not differ significantly from the link costs LK so that the least hops metrics are still valid when carrying out the method according to the invention.

Figure 3b lists the route costs RK for the routes $R_{1j-k}$ listed in Figure 2, which have been determined in accordance with the formula quoted in Figure 2 for determining the route costs RK, based on the amended link costs quoted in Figure 3a. If the optional transmission path $U_{14}$ is ignored, the route $R_{14-1}$ is the optimum route RMIN with the lowest route costs RK of all the routes R. The route $R_{14-1}$ is at the same time the optimum connection route RMIN(V) for the requested connection V to the switching node $K_4$ since, although it has the same number of hops as the route $R_{14-2}$, its route costs RK are, however, marginally lower. Taking account of the optional transmission path $U_{14}$, the route $R_{12-1}$ is the optimum route RMIN, with the lowest route costs RK of all the routes R. In this case, the route $R_{14-3}$ is the optimum-connection route RMIN(V) for the requested connection V to the switching node $K_4$, since it has one hop fewer than the routes $R_{14-1}$ and $R_{14-2}$, that is to say the number EPS ($U_{14}$) which is relevant to the route $R_{14-3}$ admittedly has by far the greatest absolute value compared to all the numbers EPS, but this does not substantially change the link costs LK, so that the least hops optimization metrics are still valid.

For the exemplary embodiment, it is assumed that switching node $K_1$ originates a request VA to set up a connection V to the connection destination VZ. This connection destination VZ is assumed to be the switching node $K_4$, and the connection V is thus assumed to be the connection $V_{14}$. In order to restrict the search area, the switching node $K_1$ assesses only those routes R ($V_{14}$) which are relevant for this connection

$V_{14}$, that is to say the routes $R_{14-1}$, $R_{14-2}$ and $R_{14-3}$. The numbers EPS are formed for these routes by using a random number generator, and the amended link costs L are then

formed. These amended link costs L are used, as the basis for a program for example, which carries out the deterministic Dijkstra algorithm to determine the optimum-connection route RMIN ($V_{14}$), that is to say the route $R_{14-3}$, when the possibly overloaded and/or interrupted transmission path $U_{14}$ is taken into account, otherwise the route $R_{14-1}$. If the state of the transmission path $U_{14}$ is known, for example by the state being reported in the network by means of a flooding method, this is considered, for example, by excluding the transmission path $U_{14}$ from the routing process for the duration of the overloading and/or interruption, for example by assigning it very high link costs LK in comparison to the link costs LK of the transmission paths U which are not overloaded and/or interrupted. Following the routing process, the requested connection $V_{14}$ is set up along the optimum-connection route RMIN ($V_{14}$).

Particularly noted advantages are claimed when using the invention in connection-oriented networks with source routing, for example ATM networks. In networks such as these, a largely uniform distribution of requested connections over a number of optimum-connection routes RMIN (V) can be achieved, for example, statistically on average, provided the numbers EPS are formed once again regularly, for example for each requested connection V. If the numbers EPS are in this case formed, for example, using a random number generator, this therefore results in different route costs RK for the relevant routes R (V) on each occasion. In the exemplary embodiment, the routes $R_{14-1}$ and $R_{14-2}$ have the route costs RK ($R_{14-1}$) = 2.005 and RK ($R_{14-2}$) = 2.019. The route costs for the next requested connection $V_{14}$ could be, for example, RK ($R_{14-1}$) = 2.023 and RK ($R_{14-2}$) = 2.004, with the route $R_{14-2}$ in consequence being determined as the optimum-connection

route RMIN ($V_{14}$). If the link costs LK were not amended, both routes $R_{14-1}$, $R_{14-2}$ would have identical route costs RK ($R_{14-1}$) = RK ($R_{14-2}$) $\doteq$ 2. In this case, owing to the deterministic behavior of the routing algorithm, the same optimum-connection route RMIN ($V_{14}$) would be determined for each

requested connection V, for example the route $R_{14-1}$. No connections would be set up along the route $R_{14-2}$ until the route $R_{14-1}$ was completely full. A major advantage of this largely uniform distribution is that, on average, it results in the rejection probability for a number of connections, whose requested data rate generally varies randomly, being reduced significantly. The rejection probability is advantageously reduced even further by using a flooding method, for example the PNNI method, in the network, in order to exclude overloaded and/or interrupted transmission paths from routing, at least during the time period when the route is overloaded and/or interrupted.

It should be mentioned that the invention can, of course, also be applied to any desired communications networks KN, in particular connectionless communications networks KN such as the packet-oriented Internet. In the Internet for example, each individual packet is transmitted along a packet-specific route R, that is to say each packet's route in a virtual connection V is independent of the routes R of the previous and subsequent packets within the same virtual connection V; the switching nodes K, which, for example, are in the form of Internet Routers, in this case in each case determine only the next switching node K for each packet in a virtual connection V - referred to as a "hop" in the specialist world. In accordance with the method according to the invention, each router distributes possibly successive packets, which are associated with the same virtual connection V, over a number of transmission paths U. The transmission paths U which are connected to one router are in this case advantageously uniformly loaded, on average. In this case, for example, different delay times for the individual packets can lead to changes in the original sequence of the packets. In this case, the original sequence of the packets in the virtual

connection V is reproduced in the receiver using a higher protocol layer.

A number of methods are known for this, for example the Transport Control Protocol TCP.

Patent Claims

1. A method for assessment of routes (R) in a communications network (KN) which comprises switching nodes (K) and transmission paths (U), in which
   - link costs (LK) which are assigned to the transmission paths (U) are used to form amended link costs (L), and
   - the routes (R) are assessed as a function of the amended link costs (L).

2. The method as claimed in claim 1, characterized in that the amended link costs (L) are formed by addition of randomly selected real numbers (EPS) to the link costs (L), with the absolute magnitude of the real numbers (EPS) being less than a maximum number, which is selected to be sufficiently small that the link costs (LK) are not substantially changed.

3. The method as claimed in one of claims 1 or 2, characterized in that an optimum route (RMIN), which is defined as a function of the amended link costs (L), is determined by means of a deterministic routing algorithm.

4. The method as claimed in claim 3, characterized in that the deterministic routing algorithm is in the form of a Dijkstra algorithm.

5. The method as claimed in one of the preceding claims, characterized

in that the communications network (KN) assesses relevant routes (R(V)) only for one requested connection (V).

6. The method as claimed in claim 5, characterized in that the routes (R) are assessed for each request for a connection (V).

7. An application of the method as claimed in one of claims 1 to 6 to a method for setting up a connection (V) in a communications network (KN) which comprises switching nodes (K) and transmission paths (U), in which the connection (V) is set up along a route (RMIN(V)) which is optimum for this connection.

8. The method as claimed in claim 7, characterized in that the route (RMIN(V)) which is optimum for the connection (V) is determined by that switching node (K) which processes the request (VA) for the connection (V).

9. The method as claimed in claim 8, characterized in that the optimum route (RMIN(V)) for the requested connection (V) is reported to all the switching nodes (K) along the optimum route (RMIN(V)) for the requested connection (V) while the connection is set up.

GR 99 P 1786


Abstract

Method for assessment of routes in a communications network

In order to assess routes R in a communications network KN comprising switching nodes K and transmission paths U, the link costs LK assigned to the transmission paths U are used - preferably with the aid of random numbers - to form amended link costs L, and the routes R are assessed as a function of the amended link costs L. If the amended link costs L are formed for every connection request, connections V which can be set up along a number of routes R with the same minimum route costs RK are distributed uniformly between these routes R while retaining existing routing algorithms.

Figure 2

PCT

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**Veröffentlicht**
*Ohne internationalen Recherchenbericht und erneut zu veröffentlichen nach Erhalt des Berichts.*

(54) Title: METHOD FOR EVALUATING ROUTES IN A COMMUNICATIONS NETWORK

(54) Bezeichnung: VERFAHREN ZUR BEWERTUNG VON ROUTEN IN EINEM KOMMUNIKATIONSNETZ

| RINF ($K_1$) | R ($V_{1x}$) | RK ($R_{1x}$) |
|---|---|---|
| R ($V_{12}$) | $R_{12\text{-}1}$ ($K_1$ => $K_2$)<br>$R_{12\text{-}2}$ ($K_1$ => $K_3$ => $K_4$ => $K_2$)<br>$R_{12\text{-}3}$ ($K_1$ => $K_4$ => $K_2$) | RK ($R_{12\text{-}1}$) = L ($U_{12}$)<br>RK ($R_{12\text{-}2}$) = L ($U_{13}$) + L ($U_{34}$) + L ($U_{24}$)<br>RK ($R_{12\text{-}3}$) = L ($U_{14}$) + L ($U_{24}$) |
| R ($V_{13}$) | $R_{13\text{-}1}$ ($K_1$ => $K_2$ => $K_4$ => $K_3$)<br>$R_{13\text{-}2}$ ($K_1$ => $K_3$)<br>$R_{13\text{-}3}$ ($K_1$ => $K_4$ => $K_3$) | RK ($R_{13\text{-}1}$) = L ($U_{12}$) + L ($U_{24}$) + L ($U_{34}$)<br>RK ($R_{13\text{-}2}$) = L ($U_{13}$)<br>RK ($R_{13\text{-}3}$) = L ($U_{14}$) + L ($U_{34}$) |
| R ($V_{14}$) | $R_{14\text{-}1}$ ($K_1$ => $K_2$ => $K_4$)<br>$R_{14\text{-}2}$ ($K_1$ => $K_3$ => $K_4$)<br>$R_{14\text{-}3}$ ($K_1$ => $K_4$) | RK ($R_{14\text{-}1}$) = L ($U_{12}$) + L ($U_{24}$)<br>RK ($R_{14\text{-}2}$) = L ($U_{13}$) + L ($U_{34}$)<br>RK ($R_{14\text{-}3}$) = L ($U_{14}$) |

(57) Abstract

The aim of the invention is to evaluate routes R in a communications network (KN) consisting of switching nodes (K) and of transmission paths (U). To this end, modified link costs (L) are established from link costs (LK) assigned to the transmission paths (U), preferably using random numbers, and the routes (R) are evaluated according to the modified link costs (L). If the modified link costs (L) are established with each call request, connections (V), which can be set–up along a number of routes (R) with identical minimal route costs (RK), are evenly distributed on these routes (R) while retaining existing routing algorithms.

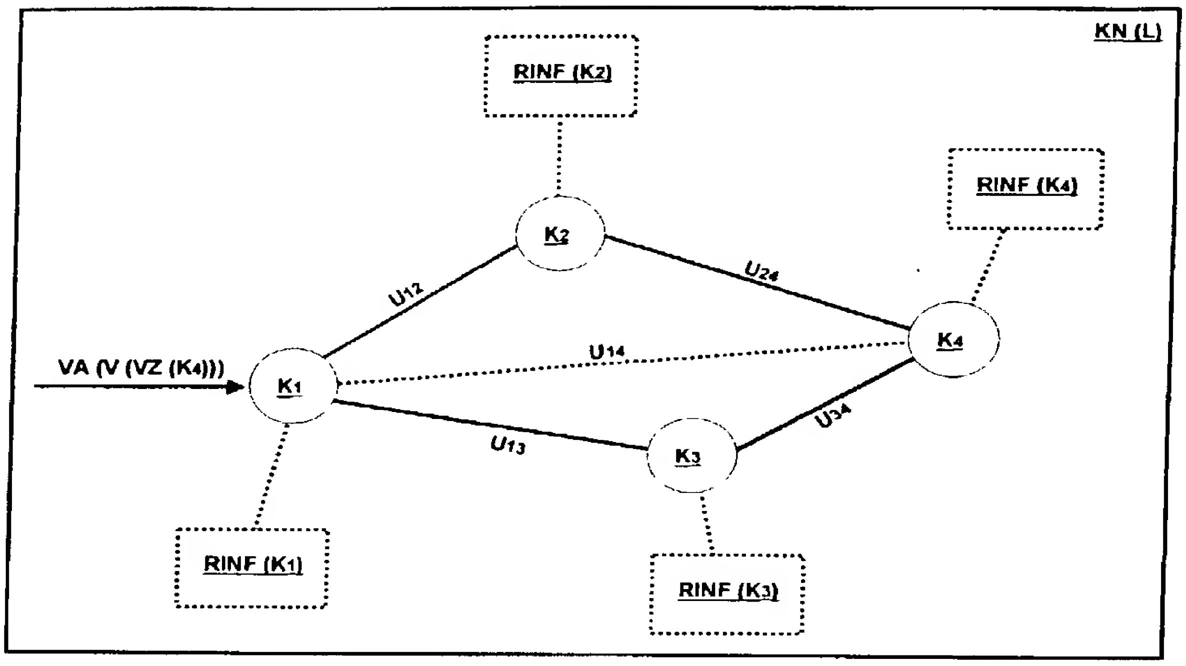


FIG 1

| RINF ($K_1$) | R ($V_{1x}$) | RK ( $R_{1x}$ ) |
|---|---|---|
| R ($V_{12}$) | $R_{12\text{-}1}$ ($K_1 \Rightarrow K_2$) | RK ($R_{12\text{-}1}$) = L ($U_{12}$) |
| | $R_{12\text{-}2}$ ($K_1 \Rightarrow K_3 \Rightarrow K_4 \Rightarrow K_2$) | RK ($R_{12\text{-}2}$) = L ($U_{13}$) + L ($U_{34}$) + L ($U_{24}$) |
| | $R_{12\text{-}3}$ ($K_1 \Rightarrow K_4 \Rightarrow K_2$) | RK ($R_{12\text{-}3}$) = L ($U_{14}$) + L ($U_{24}$) |
| R ($V_{13}$) | $R_{13\text{-}1}$ ($K_1 \Rightarrow K_2 \Rightarrow K_4 \Rightarrow K_3$) | RK ($R_{13\text{-}1}$) = L ($U_{12}$) + L ($U_{24}$) + L ($U_{34}$) |
| | $R_{13\text{-}2}$ ($K_1 \Rightarrow K_3$) | RK ($R_{13\text{-}2}$) = L ($U_{13}$) |
| | $R_{13\text{-}3}$ ($K_1 \Rightarrow K_4 \Rightarrow K_3$) | RK ($R_{13\text{-}3}$) = L ($U_{14}$) + L ($U_{34}$) |
| R ($V_{14}$) | $R_{14\text{-}1}$ ($K_1 \Rightarrow K_2 \Rightarrow K_4$) | RK ($R_{14\text{-}1}$) = L ($U_{12}$) + L ($U_{24}$) |
| | $R_{14\text{-}2}$ ($K_1 \Rightarrow K_3 \Rightarrow K_4$) | RK ($R_{14\text{-}2}$) = L ($U_{13}$) + L ($U_{34}$) |
| | $R_{14\text{-}3}$ ($K_1 \Rightarrow K_4$) | RK ($R_{14\text{-}3}$) = L ($U_{14}$) |

FIG 2

| $\underline{L}$ | LK ($U_{ij}$) | EPS ($U_{ij}$) | L ($U_{ij}$) |
|---|---|---|---|
| $U_{12}$ | 1 | 0.003 | 1.003 |
| $U_{13}$ | 1 | 0.005 | 1.005 |
| $U_{14}$ | 1 | 0.012 | 1.012 |
| $U_{24}$ | 1 | 0.002 | 1.002 |
| $U_{34}$ | 1 | 0.007 | 1.007 |

FIG 3a

RMIN

RMIN ($V_{14}$)

| $\underline{RK\ (K_1)}$ | RK ( $R_{1x}$ ) |
|---|---|
| $R_{12\text{-}1}$ | 1.003 |
| $R_{12\text{-}2}$ | 3.021 |
| $R_{12\text{-}3}$ | 2.007 |
| $R_{13\text{-}1}$ | 3.012 |
| $R_{13\text{-}2}$ | 1.012 |
| $R_{13\text{-}3}$ | 2.012 |
| $R_{14\text{-}1}$ | 2.005 |
| $R_{14\text{-}2}$ | 2.019 |
| $R_{14\text{-}3}$ | 1.012 |

FIG 3b

**COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY**
(Includes Reference to PCT International Applications) PCT/EP00/03625

ATTORNEY'S DOCKET NUMBER 112740-326

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

**METHOD FOR ASSESSING ROUTES IN A COMMUNICATIONS NETWORK**

the specification of which (check only one item below):

☐ is attached hereto.

☒ was filed as United States application Serial No. 09/979,540
on November 5, 2001,
and was amended
on ______ (if applicable).

☐ was filed as PCT international application
Number ______
on ______.
and was amended under PCT Article 19
on ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

**PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:**

| COUNTRY (if PCT indicate "PCT") | APPLICATION NUMBER | DATE OF FILING (day, month, year) | PRIORITY CLAIMED UNDER 35 USC 119 |
|---|---|---|---|
| European | 99108920.2 | 05 May 1999 | ☒ YES ☐ NO |
| | | | ☐ YES ☐ NO |
| | | | ☐ YES ☐ NO |
| | | | ☐ YES ☐ NO |
| | | | ☐ YES ☐ NO |

**(Continued)** (Includes Reference to PCT International Applications) PCT/EP00/03625 — ATTORNEY'S DOCKET NO. 112740-326

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject mater of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code. §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application(s) and the national or PCT International filing date of this application:

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) Holby M. Abern (P47,372), Robert M. Barrett (30,142), Alan L. Barry (30,819), Thomas C. Basso (46,541), Jeffrey H. Canfield (38,404), Robert W. Connors (46,639), Amy J. Gast (41,773), Timothy L. Harney (38,174), Patricia A. Kane (46,446), Michael S. Leonard (37,557), Edward A. Lehman (22,312), Adam H. Masia (35,602), Dante J. Picciano (33,543), Renato L. Smith (45,117), Maurice E. Teixeira (45,646), William E. Vaughan (39,056), Austin Victor (47,154), and all members of the firm of Bell, Boyd & Lloyd LLC.

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| | POST OFFICE ADDRESS | POST OFFICE ADDRESS | CITY | STATE & ZIP CODE/COUNTRY |

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

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|---|---|---|
| Chummun | | |
| DATE 22 · 05 · 02 | DATE | DATE |

**(Continued)** (Includes Reference to PCT International Applications) PCT/EP00/03625

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| 205 | FULL NAME OF INVENTOR | FAMILY NAME FISCHER | FIRST GIVEN NAME GERHARD | SECOND GIVEN NAME |
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| SIGNATURE OF INVENTOR 204 | SIGNATURE OF INVENTOR 205 | SIGNATURE OF INVENTOR 206 |
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| | Dipl. Ing. Gerhard Fischer | |
| DATE | DATE 22. May 2002 | DATE |

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| DATE 17/05/2002 | DATE | DATE |

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